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Effects of Pharmaceuticals and Personal Care Products on Insects

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Insects are among the most valuable living organisms on our planet. They pollinate crops, recycle dead organic matter, improve soil fertility, regulate pest populations, and serve as food for many birds, fish, and other animals. Healthy insect populations are essential for agriculture, biodiversity, and the overall balance of nature. While habitat destruction, climate change, and pesticide use are well-known threats to insects, another less obvious danger is gaining attention—pollution from pharmaceuticals and personal care products (PPCPs). Although these products are designed to improve human health and hygiene, their chemical residues often persist in rivers, lakes, soil, and groundwater.

How Do Medicines Reach Insect Habitats?

When people consume medicines, the body does not completely break down every chemical compound. A portion of these substances is excreted and enters sewage systems. Similarly, chemicals from soaps, shampoos, cosmetics, and other personal care products are washed down household drains. Most wastewater treatment plants are designed to remove organic waste and harmful microorganisms, but they are not fully effective at eliminating many pharmaceutical compounds. Consequently, small amounts of these chemicals remain in treated water and are released into rivers, ponds, lakes, and agricultural lands. Researchers have frequently detected compounds such as caffeine, carbamazepine, diclofenac, ibuprofen, and several antibiotics in wastewater, surface water, groundwater, and sediments. Even though these chemicals are present in low concentrations, continuous exposure can affect insects that spend part or all of their life cycle in these environments. Aquatic insects including mayflies, dragonflies, damselflies, caddisflies, and mosquitoes—are particularly vulnerable because their eggs, larvae, or nymphs develop directly in contaminated water. This increases the likelihood of long-term exposure throughout their development. Example: Ibuprofen discarded into drains can reach ponds where dragonfly larvae develop.

Hidden Pollution in Water Ecosystems

Rivers and lakes receiving treated wastewater often become silent reservoirs of pharmaceutical pollutants. Since many insect species live, feed, and reproduce in these aquatic habitats, they cannot avoid contact with these chemicals. This contamination does not stop with insects. Fish, spiders, birds, amphibians, and other animals that feed on contaminated insects may also absorb these chemicals. As pollutants move from one organism to another, they travel through the food chain, potentially affecting entire ecosystems. Because pharmaceutical pollution is often invisible and difficult to detect, its environmental impacts can remain unnoticed for years. Understanding this hidden threat is essential for protecting insects and maintaining healthy ecosystems. Example: Swedish rivers contained 33 pharmaceuticals in aquatic insects, with tetracycline reaching 260 ng/g.

Effects on Insect Health and Development

Although pharmaceutical residues are usually present in the environment in very small amounts, continuous exposure can have significant effects on insect health. Many of these

chemicals interfere with normal biological functions that are essential for growth, survival, and reproduction. Studies have shown that pharmaceutical pollutants can slow insect development, reduce reproductive success, weaken immunity, and alter metabolism. These changes may not be immediately visible, but over time they can reduce insect populations and affect their ability to adapt to environmental challenges. One major concern is oxidative stress. Under normal conditions, insects maintain a balance between harmful molecules known as reactive oxygen species and natural antioxidant defenses. Exposure to certain medicines can disturb this balance, causing damage to cells and tissues. As a result, insects may become weaker, more vulnerable to diseases, and less capable of surviving environmental stress. Research on silkworms provides a good example of these effects. Scientists observed that exposure to certain antibiotics influenced larval growth, reduced cocoon production, and altered the activity of important genes. Since silkworms are economically valuable insects, these findings suggest that pharmaceutical pollution could also affect insects that contribute directly to agriculture and rural livelihoods. Example: Diclofenac reduced antioxidant enzymes and increased oxidative stress in the cockroach *Nauphoeta cinerea.*

Changes in Insect Behaviour

Many medicines are designed to influence the human nervous system. Surprisingly, some of these chemicals can also affect insects because they share several basic biological pathways related to nerve function. Even small amounts of antidepressants and antihistamines present in contaminated water have been reported to change the behaviour of aquatic insects. Their movement patterns, feeding habits, and responses to danger may all be affected. For example, dragonfly and damselfly larvae exposed to pharmaceutical residues may react more slowly when predators approach. Instead of escaping quickly, they may show delayed or unusual defensive behaviour, increasing their chances of being captured. Such behavioural changes can disturb the natural balance between predators and prey.

Impact on Beneficial Microorganisms Inside Insects

The digestive system of insects contains millions of beneficial microorganisms collectively known as the gut microbiota. These microbes perform several important functions, including helping insects digest food, absorb nutrients, strengthen immunity, and adapt to changing environmental conditions. However, antibiotics released into the environment do not affect only harmful bacteria. They can also disrupt these beneficial microbial communities living inside insects. Scientific studies have shown that antibiotic contamination can reduce microbial diversity and alter the natural balance of bacteria in the insect gut. As a result, insects may experience poor digestion, slower growth, reduced lifespan, weakened disease resistance, and lower reproductive performance. Example: Ciprofloxacin altered gut bacteria in the oriental fruit moth (*Grapholita molesta*), reducing growth and reproduction.

Threat to Food Chains and Biodiversity

Aquatic insects are especially important in this process. During their life cycle, many species emerge from water as winged adults and move into terrestrial habitats. In doing so, they can carry accumulated pharmaceutical residues from rivers and ponds to land-based ecosystems. Birds, spiders, bats, and other insect-eating animals may then be exposed to these chemicals through their diet. Although the long-term ecological consequences are still being investigated, scientists are increasingly concerned that continuous pharmaceutical pollution could disrupt natural food webs and reduce biodiversity. A decline in insect populations or changes in their health and behaviour may affect many other organisms that depend on them for survival. Protecting insects, therefore, means protecting the stability and resilience of entire ecosystems. Example: Carbamazepine accumulated in aquatic insects and was transferred to tree swallows through contaminated prey.

Need for Sustainable Solutions

Reducing pharmaceutical pollution requires the combined efforts of governments, industries, healthcare professionals, researchers, and the general public. Since these pollutants originate from everyday human activities, everyone has a role to play in minimizing their release into the environment. One of the most important steps is improving wastewater treatment technologies so that pharmaceutical residues can be removed more effectively before treated water is discharged into natural ecosystems. Proper disposal of unused or expired medicines is equally essential, as throwing them into household drains or open waste systems increases environmental contamination. The responsible use of antibiotics and other medicines can also reduce the amount of chemical residues entering water bodies. In addition, regular monitoring of pharmaceutical pollutants in rivers, lakes, and agricultural ecosystems will help scientists understand their distribution and ecological impact. Example: Community medicine take-back programs prevent drugs from entering waterways.

Conclusion

Modern medicines and personal care products have transformed human health and improved the quality of life for millions of people. However, their benefits should not overshadow their unintended environmental consequences. As vital pollinators, decomposers, natural pest regulators, and key members of food webs, insects play an indispensable role in maintaining ecological balance. Protecting them requires expanding our understanding of pollution beyond traditional pesticides and recognizing pharmaceutical residues as an emerging environmental challenge.

Reference

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